

IN THE CLAIMS:

The following is a complete listing of the claims, and replaces all earlier listings and all earlier versions.

Claim 1. (Previously Presented): A method of encoding a digital image comprising a plurality of pixels, the image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the method comprising the steps of:

- a) dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;
- b) selecting a current tile;
- c) decomposing the current tile, using the DWT, to one level of decomposition to form a plurality of subbands including a LL, LH, HL and HH subband;

- d) accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of the specified block size, and encoding each block to a bit stream;
- e) accumulating LL subband coefficients and repeating steps b) to e) until a predetermined number of coefficients, dependent on the specified block size, of the LL subband have been accumulated;
- f) assigning as a current tile the predetermined number of accumulated LL sub-band coefficients;
- g) repeating steps c) to f) until the predetermined level of DWT decomposition is reached; and
- h) encoding the LL subband into the bit stream.

Claim 2. (Original): A method according to claim 1, wherein accumulating coefficients in each subband includes accumulating coefficients in corresponding subbands of different tiles.

Claim 3. (Original): A method according to claim 1, wherein encoding comprises encoding each block substantially as each block is accumulated.

Claim 4. (Previously Presented): A method according to claim 1, wherein the specified block size comprises H coefficients in the first dimension by W coefficients in the second dimension.

Claim 5. (Previously Presented): A method according to claim 4, wherein the number of coefficients in the first dimension is equal to the number of coefficients in the second dimension ($W=H$).

Claim 6. (Previously Presented): A method according to claim 4, wherein the predetermined level of DWT decomposition is J and the minimum number of pixels in a first dimension of each tile is defined by $2^J H + O(2^J - 1)$, where O is an overlap required by the DWT filter.

Claim 7. (Previously Presented): A method according to claim 6, wherein the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W + O$.

Claim 8. (Previously Presented): A method according to claim 6, wherein the DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients coefficient ($O=7$).

Claim 9. (Previously Presented): A method according to claim 6, wherein the DWT filter is a Haar filter and the overlap required is no pixels or coefficient ($O=0$).

Claim 10. (Previously Presented): A method of encoding a digital image comprising a plurality of pixels, the image being able to be transformed by a discrete

wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the method comprising the steps of:

a) dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;

b) selecting a tile of the image as a current tile;

c) decomposing the current tile, using the DWT, to provide a plurality of coefficients in LL, LH, HL and HH subbands;

d) encoding coefficients of the LH, HL, HH subbands of a current level of DWT decomposition into a bit-stream;

e) determining if the current level of DWT decomposition is the predetermined level of DWT decomposition, including

ea) encoding the coefficients of the LL subband into the bitstream, if the current level of DWT decomposition is the predetermined level of DWT decomposition, and repeating steps b) to e), and

eb) storing coefficients not previously encoded of the LL subband if the current level of DWT decomposition is not the predetermined level of DWT decomposition; and

f) determining if the number of stored coefficients of the LL subband at the current level of DWT decomposition is at least a predetermined number dependent on the specified block size, including

fa) assigning the predetermined number of LL coefficients as a current tile, if the number of stored LL coefficients is at least the predetermined number, and repeating steps c) to f), and

fb) repeating steps b) to f) if the number of stored LL coefficients is less than the predetermined number.

Claim 11. (Previously Presented): A method according to claim 10, wherein the specified block size comprises H coefficients in the first dimension by W coefficients in the second dimension.

Claim 12. (Previously Presented): A method according to claim 11, wherein the number of coefficients in the first dimension is equal to the number of coefficients in the second dimension of the specified block ($W=H$).

Claim 13. (Previously Presented): A method according to claim 11, wherein the predetermined level of DWT decomposition is J and the minimum number of

pixels in a first dimension of each tile is defined by $2^J H + O(2^J - 1)$, where O is an overlap required by the DWT filter.

Claim 14. (Previously Presented): A method according to claim 13, wherein the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W+O$.

Claim 15. (Previously Presented): A method according to claim 13, wherein the DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficient ($O=7$).

Claim 16. (Previously Presented): A method according to claim 13, wherein the DWT filter is a Haar filter and the overlap required is no pixels or coefficient ($O=0$).

Claim 17. (Previously Presented): A method according to claim 10, wherein the encoding is preformed by a Bit-plane entropy Encoder.

Claim 18. (Previously Presented): A method according to claim 10, wherein the encoding is preformed by an Arithmetic Encoder.

Claim 19. (Previously Presented): A method according to claim 10, wherein the encoding is preformed by a hybrid encoder comprising an Arithmetic and Bit-plane entropy Encoder.

Claim 20. (Currently Amended): An apparatus for encoding an image, the image being capable of being transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the apparatus comprising:

- a) means for dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;
- b) selecting means for selecting a current tile;
- c) decomposing means for decomposing the current tile using the DWT to one level of decomposition to form a plurality of subbands including a LL, LH, HL and HHH subband;
- d) means for accumulating a predetermined number of coefficients, dependent on the specified block size, of the LL sub-band coefficients;

- e) means for assigning, as a current tile, the predetermined number of accumulated LL subband coefficients;
- f) means for feeding back the current tile to the decomposing means for decomposing the current tile to a further level of decomposition;
- g) means for accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of the specified block size, and accumulating at least one block of the specified block size in the LL subband at the predetermined level; and
- h) encoding means for encoding each block to a bit stream as each block is formed, wherein said encoding means (h) encodes LH, HL and HH subbands to the bit stream when said accumulating means (g) forms corresponding blocks of the specified block size.

Claim 21. (Previously Presented): An apparatus for encoding an image, the image being capable of being transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and capable of being encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the apparatus comprising:

storage means for storing at least a portion of the image, the portion of the image having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater

than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;

first and second filtering means for successively applying a linear transform to a first dimension and a second dimension of corresponding image portions respectively to provide LL, LH, HL and HH subbands, each subband comprising at least one coefficient;

partial band storage means for accumulating a predetermined number of coefficients, dependent on the specified block size, of the LL subband, and using the accumulated LL coefficient as an image portion for refiltering by said first and second filtering means to achieve a next level decomposition;

subband storage means for accumulating the blocks of specified block size for each level in the LH, HL and HH subbands, and accumulating the blocks of specified block size in the LL subband at the predetermined level of decomposition; and

encoder means for encoding each accumulated block into a bit stream as each block is formed, wherein said encoder means encodes the LH, HL and HH subbands to the bit stream when said subband storage means accumulates corresponding blocks of the specified block size.

Claim 22. (Original): An apparatus according to claim 20, wherein said encoder means is a bit-plane entropy encoder.

Claim 23. (Original): An apparatus according to claim 21, wherein said encoder means is a bit-plane entropy encoder.

Claim 24. (Original): An apparatus according to claim 20, wherein said encoder means is an Arithmetic Encoder.

Claim 25. (Original): An apparatus according to claim 21, wherein said encoder means is an Arithmetic Encoder.

Claim 26. (Original): An apparatus according to claim 20, wherein said encoder means is a hybrid encoder comprising an Arithmetic Encoder and Bit-plane entropy Encoder.

Claim 27. (Original): An apparatus according to claim 21, wherein said encoder means is a hybrid encoder comprising an Arithmetic Encoder and Bit-plane entropy Encoder.

Claim 28. (Previously Presented): A computer readable memory medium for storing a program for an apparatus which encodes a digital image comprising a plurality of pixels, the image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block

basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, said program comprising:

a) code for a dividing step, of dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;

b) code for a selecting step, of selecting a current tile;

c) code for a decomposing step, of decomposing the current tile, using the DWT, to one level of decomposition to form a plurality of subbands including an LL, LH, HL and HH subband;

d) code for an accumulating step, of accumulating coefficients in each subband of the LH, HL and HH subbands to form blocks of the specified block size and for encoding each block to a bit stream;

e) code for an accumulating step, of accumulating LL subband coefficients, and for repeating steps b) to e) until a predetermined number of coefficients, dependent on the specified block size, of the LL subband have been accumulated;

f) code for an assigning step, of assigning as a current tile the predetermined number of accumulated LL subband coefficients;

g) code for repeating steps c) to g) until the predetermined level of DWT decomposition is reached; and

h) code for an encoding step, of encoding the LL subband into the bit stream.

Claim 29. (Original): A computer readable memory medium according to claim 28, wherein said code for accumulating coefficients in each subband is adapted to include steps for accumulating coefficients in corresponding subbands of different tiles.

Claim 30. (Original): A computer readable memory medium according to claim 28, wherein said code for encoding is adapted to include steps for encoding each block substantially as each block is accumulated.

Claim 31. (Previously Presented): A computer readable memory medium according to claim 28, said code being adapted so that the specified block size comprises H coefficients in the first dimension by W coefficients in the second dimension.

Claim 32. (Previously Presented): A computer readable memory medium according to claim 31, said code being adapted so that the number of coefficients in the first dimension is equal to the number of coefficients on the second dimension ($W=H$).

Claim 33. (Previously Presented): A computer readable memory medium according to claim 31, said code being adapted so that the predetermined level of DWT decomposition is J and the minimum number of pixels in a first dimension of each tile is defined by $2^J H + O(2^J - 1)$, where O is an overlap required by the DWT filter.

Claim 34. (Original): A computer readable memory medium according to claim 33, said code being adapted so that the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W + O$.

Claim 35. (Previously Presented): A computer readable memory medium according to claim 33, said code being adapted so that the DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients ($O=7$).

Claim 36. (Previously Presented): A computer readable memory medium according to claim 33, said code being adapted so that the DWT filter is a Haar filter and the overlap required is no pixels or coefficients ($O=0$).

Claim 37. (Previously Presented): A computer readable memory medium for storing a program for an apparatus which encodes a digital image comprising a plurality of pixels, the image being able to be transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition and capable of being encoded on a block by block

basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, said program comprising:

a) code for a dividing step, of dividing the image into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, wherein the predetermined level of DWT decomposition is greater than one, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition;

b) code for a selecting step, of selecting a tile of the image as a current tile;

c) code for a decomposing step, of decomposing the current tile, using the DWT filter, to provide a plurality of coefficients in LL, LH, HL and HH subbands;

d) code for an encoding step, of encoding coefficients of the LH, HL, and HH subbands of a current level of DWT decomposition into a bitstream;

e) code for a determining step, of determining if the current level of DWT decomposition is the predetermined level of DWT decomposition, including

ea) code for an encoding step, of encoding the coefficients of the LL subband into the bitstream, if the current level of DWT decomposition is the predetermined level of DWT decomposition, and repeating steps b) to e), and

eb) code for a storing step, of storing coefficients not previously encoded of the LL subband if the current level of DWT decomposition is not the predetermined level of DWT decomposition; and

f) code for a determining step, of determining if the number of the stored coefficients of the LL subband at the current level of DWT decomposition is at least a predetermined number dependent on the specified block size, including

fa) code for an assigning step, of assigning the predetermined number of LL coefficients as a current tile, if the number of stored LL coefficients is at least the predetermined number, and repeating steps c) to f), and

fb) code for a repeating step, of repeating steps b) to f) if the number of stored LL coefficients is less than the predetermined number.

Claim 38. (Previously Presented): A computer readable memory medium according to claim 37, said code being adapted so that specified block size comprises H coefficients in the first dimension by W coefficients in the second dimension.

Claim 39. (Previously Presented): A computer readable memory medium according to claim 38, said code being adapted so that the number of coefficients in the first dimension is equal to the number of coefficients in the second dimension of the specified block ($W=H$).

Claim 40. (Previously Presented): A computer readable memory medium according to claim 38, said code being adapted so that the predetermined level of DWT decomposition is J and the minimum number of pixels in a first dimension of each tile is defined by $2^J H + O(2^J - 1)$, where O is an overlap required by the DWT filter.

Claim 41. (Previously Presented): A computer readable memory medium according to claim 40, said code being adapted so that the number of pixels in a second dimension of each tile is less than that of the first dimension and is defined by $2W + O$.

Claim 42. (Previously Presented): A computer readable memory medium according to claim 40, said code being adapted so that the DWT filter is a Daubechies 9/7 filter and the overlap required is 7 pixels or coefficients ($O=7$).

Claim 43. (Previously Presented): A computer readable memory medium according to claim 40, said code being adapted so that the DWT filter is a Haar filter and the overlap required is no pixels or coefficients ($O=0$).

Claim 44. (Original): A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to perform encoding in accordance with a bit-plane entropy encoding process.

Claim 45. (Original): A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to perform encoding in accordance with an Arithmetic Encoding process.

Claim 46. (Original): A computer readable memory medium according to claim 37, wherein said steps for encoding are adapted to performed encoding in accordance with a hybrid encoding process comprising Arithmetic and Bit-plane entropy encoding sub-processes.

Claim 47. (Canceled)

Clam 48. (Previously Presented): A method of encoding a digital image on a block by block basis, block having a specified block size in number of coefficients, the method comprising the steps of:

- a) dividing the image into a plurality of tiles, each tile having a number of pixels less than required to produce the number of coefficients in the block, to decompose each tile to form a plurality of subbands including a LL, LH, HL and HH subband by using a discrete wavelet transform (DWT) to a predetermined level of decomposition greater than one;
- b) selecting a current tile;
- c) decomposing the current tile to form a plurality of subbands including a LL, LH, HL and HH subband by using the DWT;

- d) encoding LH, HL and HH subbands to a bit stream;
- e) accumulating LL subband coefficients and repeating steps b) to e) until a predetermined number of coefficients, dependent on the specified block size, of the LL subband have been accumulated;
- f) assigning, as a current tile, the predetermined number of accumulated LL subband coefficients;
- g) repeating steps c) to g) until the predetermined level of decomposition is reached; and
- h) encoding the LL subband to the bit stream.

Claim 49. (Previously Presented): An apparatus for encoding a digital image on a block by block basis, each block having a specified block size in number of coefficients, said apparatus comprising:

- a) means for dividing the image into a plurality of tiles, each tile having a number of pixels less than required to produce the number of coefficients in the block, to decompose each tile to form a plurality of subbands including a LL, LH, HL and HH subband by using a discrete wavelet transform (DWT) to a predetermined level of decomposition greater than one;
- b) selecting means for selecting a current tile;
- c) decomposing means for decomposing the current tile to form a plurality of subbands including a LL, LH, HL and HH subband by using the DWT;

d) encoding means for encoding LH, HL and HH subbands to a bit stream;

e) means for accumulating LL subbands until a predetermined number of coefficients, dependent on the specified block size, of the LL subband have been accumulated;

f) means for assigning, as a current tile, the predetermined number of accumulated LL subband coefficients; and

g) encoding means for encoding the LL subband to the bit stream.

Claim 50. (Previously Presented): A method of decoding a digital image comprising a plurality of pixels, the image having been transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and having been encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the image having been divided into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition, the decoding method comprising substantially the inverse steps to those recited in claim 1.

Claim 51. (Previously Presented): An apparatus adapted for decoding a digital image comprising a plurality of pixels, the image having been transformed by a discrete wavelet transform (DWT) to a predetermined level of decomposition, and having been encoded on a block by block basis, each block having a specified block size in number of coefficients, in a first dimension and a second dimension, the image having been divided into a plurality of tiles, each tile having firstly, substantially a minimum number of pixels required to produce the number of coefficients in the first dimension of the block at the predetermined level of DWT decomposition, and secondly, less than a minimum number of pixels required to produce the number of coefficients in the second dimension of the block at the predetermined level of DWT decomposition, said apparatus adapted to implement the method recited in claim 50.